REMARKS/ARGUMENTS

Overview of the invention: Unwanted thermal expansion of the main pole of a magnetic write head is prevented by thermally connecting the write coil to the substrate. This is done through a thermally conductive pedestal that extends upwards from the substrate and is in turn connected to the coil though a thermally conductive layer

Reconsideration is requested of all rejections based on objections to the abstract:

A new abstract that conforms to the guidelines provided by examiner has been provided.

Reconsideration is requested of all rejections based on objections to the specification:

Examiner's explanation that his statement that there is "no antecedent basis in the specification for the microstructure as recited in the claims" is a standard form is understood but, regrettably, does not clarify the substance of the statement itself.

As examiner knows, antecedent basis need not always be the exact word or phrase for which it is serving as an antecedent (MPEP **2173.05(e) Lack of Antecedent Basis [R-5]**). In particular, a claim is indefinite when it contains words or phrases whose meaning is unclear. We do not believe this to be the case here since dimensions for this structure, quoted in several places, are all in microns, which makes it clear to anyone skilled in the art that this is a micro-structure. We have, however, changed "micro-structure" to --structure--, as required by examiner.

Regarding our arguments that demonstrate that a key part of the Jensen invention is inoperable, it appears that copies of the abstracts that we cited as part of our argument did not reach examiner. We apologize for this and provide them herewith. They will be discussed further below.

In addition to the various elements that relate to a magnetic write head, the present invention claims two novel features (not taught by Jensen) whose purpose is to cool the write coil. The latter is referred to in the specification as element 17 and can be seen in FIGs. 3-7. The first novel feature is the thermally conductive pedestal that is referenced as element 23 and can be seen in FIGs. 2-5. The second novel feature is thin film 41 that provides a high thermal conductance path between the coil and the pedestal and can be seen in FIGs. 4 and 5.

Claim 1 now reads as follows (element numbering added):

1. A method to dissipate heat generated by a coil (17) located within a structure, that is on a substrate, (10) comprising:

forming a thermally conductive pedestal (23) that originates at said substrate and extends upwards therefrom; and

forming a layer of thermally conductive material (41) that thermally connects said coil to said substrate through said pedestal, thereby providing an unbroken thermal path between said coil and said substrate.

Similarly for claim 25.

As can be seen in FIG. 5, the structure is then planarized until top magnetic pole 21 is just exposed, thereby forming heat diffuser 41 that, together with thermally conductive pedestal 23, provides an <u>unbroken</u> thermal path between the write coil(s) and the undercoat/substrate. Also, in FIG. 7, via hole 73 is overfilled with thermally conductive material and the structure is planarized until top magnetic pole 21 is just exposed. As in the first embodiment, the completed structure features heat diffuser 41 that, together with the filled via hole, provides a thermal path between the write coil(s) and the undercoat.

Note the high thermal conductance path between the coil and the substrate. Without it, heat from the coil would have to pass through several low thermal conductance layers, particularly layer 19. See later discussion below.

Reconsideration is requested of the rejection of claims 1, 3, 4, 25, 27, and 28 under 35 U.S.C. 102(b) as being anticipated by Jensen et al.

Jensen attempts to solve the coil overheating problem, in part, by underlying the coil with deposited layer 532 that is asserted to be both a good electrical insulator and a good thermal conductor. The preferred materials for this layer are stated to be aluminum nitride or silicon nitride whose thermal conductivities **when in bulk form** approach the values cited by Jensen. In the bulk material this relatively high thermal conductivity is due only to lattice conduction (by phonons). Were it otherwise they could not be good electrical insulators. However, when deposited as thin films, good lattice conduction is no longer possible because such films are polycrystalline so the phonons get scattered at the grain boundaries. Even if the films were monocrystalline, phonon reflection and absorption at the film's surfaces would reduce their thermal conductivity. This argument is based on physical principles that are well known to anyone skilled in this art.

Additionally, there is no teaching by Jensen of how the heat absorbed by layer 532 is to be removed from the vicinity of the coil. As can be seen in Jensen's figure 5, this absorbed heat must pass through lower pole 512, dielectric layer 508, and lower shield 510 before reaching substrate 506. The two "pedestals" 522 and 524, cited by examiner extend only as far as layer 518. Unlike the present invention, there is no unbroken thermal path (commonly referred to by those skilled in the art as a thermal short circuit) to convey heat directly to the substrate as is disclosed and (now) claimed in the present invention.

Note that the unbroken thermal path to which we refer is shown in our FIG. 5 as element 41 which, together with element 23, connects coil 20 to substrate 10. It can also be seen in our FIG. 7 where element 41, together with element 73, connects coil 20 to substrate 10.

Jensen's invention does not include a sub-structure, similar to our unbroken thermal path, to perform a similar function. We respectfully request that examiner demonstrate the contrary or allow our claims 1 and 25.

Reconsideration is requested of the rejection of claims 2, 5, 6, 26, and 29 under 35 U.S.C. 103(a) as being unpatentable over Jensen et al.

Regarding claims 2 and 26, examiner argues that it would have been obvious for one skilled in the art to select an insulating material having a thermal conductivity in the range recited in claims 2 and 26. With the greatest respect we had requested that examiner provide us with but a single example of a material that, in thin film form, has been reported to be both a good electrical insulator and to have a thermal conductivity in the range 100 to 400 $W/m^{-1}K^{-1}$.

Examiner has not responded to this request but has, instead, required us to produce objective evidence to the effect that NO deposited film has EVER been reported to be both a good electrical insulator and to have a thermal conductivity in the range 100 to 400 $W/m^{-1}K^{-1}$. As examiner surely knows, it is impossible to prove a negative since we would need, in principle, to survey ALL films ever deposited. On the other hand, since examiner contends that it would be obvious to use such a film, we must assume that examiner believes that such films exist and examiner should therefore have no difficulty providing a SINGLE example of such a film, as we had requested.

As already noted, we have attached copies of statements from four authoritative sources in compliance with examiner's requirement of objective evidence. These are:

Reference 1 (Sun Rock Choi et al.) confirms that the thermal conductivity of thin films is significantly less than the corresponding bulk material.

Reference 2 (Jungho Mun et al.) shows that the thermal conductivity of as-deposited titania films is in the range of 0.7-1.7 $Wm^{-1}K^{-1}$; bulk value is 11.7 $Wm^{-1}K^{-1}$.

Reference 3 (Jansen and Obermeier) gives a value of 4 $Wcm^{-1}K^{-1}$ for a diamond film. This is a very low value compared to bulk diamond which is recognized as having a greater thermal conductivity than any other electrically insulating material.

Reference 4 (Wikipedia article on Properties of Diamond) confirms that the bulk thermal conductivity of diamond exceeds 30 $Wcm^{-1}K^{-1}$.

Applicant respectfully requests that a timely Notice of Allowance be issued in this case.

Respectfully submitted,

Saile Ackerman LLC
28 Davis Avenue
Poughkeepsie
NY 12603

By ________________

Stephen B. Ackerman
Reg. No. 37761

Reference 1

Titre du document / Document title

Thermal conductivity of AlN and SiC thin films

Auteur(s) / Author(s)

SUN ROCK CHOI ; KIM Dongsik ; CHOA Sung-Hoon ; LEE Sung-Hoon ; KIM Jong-Kuk ;

Résumé / Abstract

The thermal conductivity of AlN and SiC thin films sputtered on silicon substrates is measured employing the 3ω method. The thickness of the AlN sample is varied in the range from 200 to 2000 nm to analyze the size effect. The SiC thin films are prepared at two different temperatures, 20 and 500°C, and the effect of deposition temperature on thermal conductivity is examined. The results reveal that the thermal conductivity of the thin films is significantly smaller than that of the same material in bulk form. The thermal conductivity of the AlN thin film is strongly dependent on the film thickness. For the case of SiC thin films, however, increased deposition temperature results in negligible change in the thermal conductivity as the temperature is below the critical temperature for crystallization. To explain the thermal conduction in the thin films, the thermal conductivity and microstructure are compared using x-ray diffraction patterns.

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Measurement of the thermal conductivity of TiO_2 thin films by using the thermo-reflectance method

Jungho Mun[a], Sok Won Kim[a,], Ryozo Kato[b], Ichiro Hatta[c], Sang Hyun Lee[d] and Kweon Ho Kang[e]

[a]Department of Physics, University of Ulsan, Ulsan 680-749, Republic of Korea

[b]Ulvac-Riko Inc., Hakusan, Midoriku, Yokohama 226, Japan

[c]Fukui University of Technology, 3-6-1 Gakuen, Fukui 910-0028, Japan

[d]Division of Physical Metrology, Korea Research Institute of Standards and Science, Daejon 305-600, Republic of Korea

[e]Korea Atomic Energy Research Institute, P.O. Box 105, Yusong, Daejon 305-600, Republic of Korea

Available online 30 November 2006.

Abstract

The through-plane thermal conductivity of TiO_2 thin films, with the thicknesses of 150 and 300 nm, deposited on silicon wafers and heat treated at several different temperatures was measured using the thermo-reflectance method which utilizes the reflectance variation of the films surface produced by the periodic temperature variation. The results showed that the thermal conductivities were 0.7–1.7 W m^{-1} K^{-1} and increase as the heat treatment temperature increases. They are explained by the grain size and the density of the heat treated films. Also the thermal conductivity of 300 nm thick film is larger than that of 150 nm thick film by 30%. The reason for that was assumed to be the thermal resistance between the thin film, metal film and the substrate.

Reference (3)

Thermal conductivity measurements on thin films based on micromechanical devices

E Jansen *et al* 1996 *J. Micromech. Microeng.* **6** 118-121 doi: 10.1088/0960-1317/6/1/029 Help

E Jansen and E Obermeier
Technical University of Berlin, TIB 3.1, Gustav-Meyer-Allee 25, 13355 Berlin, Germany

Abstract. *A new, highly accurate technique to measure the thermal conductivity k(T) of thin films (thickness ranging from* $2\ \mu m$ *up to several hundred micrometres) parallel to the surface over a wide temperature range is presented. The silicon substrate on which the films were deposited is completely removed in a defined area leaving membranes or free standing beams. A thin-film heater generates a temperature profile which is measured by several thermoresistors. The shape and dimensions of the structures have been optimized using computer simulations (FEA). The measurement is carried out in a vacuum chamber. First measurements on etched silicon membranes show a good agreement with literature values for bulk silicon. Measurements on polycrystalline diamond films show a maximum value of the thermal conductivity of* $4\ W\ cm^{-1}\ K^{-1}$ *between 100 and* $200\ °C$*, which can be explained by the theory for thermal conductivity as an effect of the small grain size of the diamond film.*

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accompanied by two additional weak bands at 537 nm and 495 nm (H4 center, a large complex presumably involving 4 substitutional nitrogen atoms and 2 lattice vacancies[8]). Type IIb diamonds may absorb in the far red due to the substitutional boron, but otherwise show no observable visible absorption spectrum.

Gemological laboratories make use of spectrophotometer machines that can distinguish natural, artificial, and color-enhanced diamonds. The spectrophotometers analyze the infrared, visible, and ultraviolet absorption and luminescence spectra of diamonds cooled with liquid nitrogen to detect tell-tale absorption lines that are not normally discernible.

Electrical properties

Except for most natural blue diamonds—which are semiconductors due to substitutional boron impurities replacing carbon atoms—diamond is a good electrical insulator. Natural blue or blue-gray diamonds, common for the Argyle diamond mine in Australia, are rich in hydrogen; these diamonds are not semiconductors and it is unclear whether hydrogen is actually responsible for their blue-gray color.[9] Natural blue diamonds containing boron and synthetic diamonds doped with boron are p-type semiconductors. N-type diamond films are reproducibly synthesized by phosphorus doping during chemical vapor deposition. Diode p-n junctions and UV light emitting diodes (LEDs, at 235 nm) has been produced by sequential deposition of p-type (boron-doped) and n-type (phosporus-doped) layers.[10]

In April 2004 Nature reported that below the superconducting transition temperature 4 K, boron-doped diamond synthesized at high temperature and high pressure is a bulk, type-II superconductor[11]. Superconductivity was later observed in heavily boron-doped films grown by various chemical vapor deposition techniques, and the highest reported transition temperature (by 2008) is 11.4 K [12][13].

Thermal conductivity

Unlike most electrical insulators, diamond is a good conductor of heat because of the strong covalent bonding within the crystal. Most natural blue diamonds contain boron atoms which replace carbon atoms in the crystal matrix, and also have high thermal conductance. Monocrystalline synthetic diamond enriched in ^{12}C isotope (99.9%) has the highest thermal conductivity of any known solid at room temperature: >30 W/cm·K [14] five times more than copper. Because diamond has such high thermal conductance it is already used in semiconductor manufacture to prevent silicon and other semiconducting materials from overheating. At lower temperatures conductivity becomes even better as its Fermi electrons can match the phononic normal transport mode near the Debye point,[15] and transport heat more swiftly, to reach ~800 W/cm·K at 100 K (^{12}C enriched diamond)[14]

Diamond's thermal conductivity is made use of by jewellers and gemologists who may employ an electronic *thermal probe* to separate diamonds from their imitations. These probes consist of a pair of battery-powered thermistors mounted in a fine copper tip. One thermistor functions as a heating device while the other measures the temperature of the copper tip: if the stone being tested is a diamond, it will conduct the tip's thermal energy rapidly enough to produce a measurable temperature drop. This test takes about 2–3 seconds. However, older probes will be fooled by moissanite, an imitation of diamond introduced in 1998 which has a